A Conceptual Framework for the Implementation of the Precautionary Approach to Fisheries Management within the Northwest Atlantic Fisheries Organization (NAFO)*

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Abstract.- In June 1997, the Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO) established an *Ad hoc* Working Group to develop a conceptual framework for the implementation of the precautionary approach to fisheries management by NAFO. After undertaking a review of (1) various binding and non-binding national and international agreements embodying the Precautionary Approach and (2) various documents and reports pertaining to the consideration and implementation of the Precautionary Approach within ICES and by the USA and Canada, the *ad hoc* Working Group developed a framework and action plan for implementing the precautionary approach within NAFO. The framework prescribes actions (control laws/decision rules) for controlling F with respect to pre-defined, stock-specific, precautionary reference points for both biomass and fishing mortality (B_{lim}, B_{buf}, B_{tr}; F_{lim}, F_{buf}, F_{target}). The objectives are to ensure that $SSB >> B_{buf} > B_{lim}$ and to maintain $F_{target} <= F_{buf} < F_{lim}$. Guidance is also provided on the determination of these reference points under three levels of data richness: data-rich , data-moderate, and data-poor. A 15-month action plan was proposed for implementing and applying the precautionary approach for managing stocks within the NAFO Regulatory Area. As part of this action plan, a Scientific Council Workshop will be held during 17-27 March 1998 at NAFO HQs in Dartmouth, Nova Scotia to: (1) determine precautionary reference points for all stocks managed by NAFO; (2) specify decision rules to achieve target reference points and to avoid exceeding limit reference points; (3) develop criteria to be used in consideration of possible fisheries re-openings; (4) identify data collection and monitoring activities required to reliably evaluate resource status with respect to reference points; and (5) define research requirements to improve the quantification and evaluation of uncertainty (i.e. risk analysis), as well as methodological developments required to reduce uncertainty. At its June 1998 meeting, it is envisaged that the NAFO Scientific Council will formally implement the precautionary approach in formulating its scientific and management advice for 1999.

Introduction

During the June 1997 meeting of the NAFO Scientific Council, the Council's deliberations led to the creation of an *Ad hoc* Working Group to develop a conceptual framework for the implementation of the precautionary approach in the NAFO context. Cognizant that a number of national and international meetings and initiatives had taken place in recent years focusing on the incorporation and application of the precautionary approach in fisheries management, the Working Group conducted a review of how the precautionary approach was being addressed within ICES and by the USA and Canada. The Working Group considered the relevant sections of various binding and non-binding agreements embodying the precautionary approach:

- the UN Agreement on the Management of Straddling Fish Stocks and Highly Migratory Fish Stocks [see Appendix 1 and 2];
- the FAO Code of Conduct for Responsible Fisheries [see Appendix 3];
- and the FAO Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions [see Appendix 4].

As well, several other documents relating to overfishing definitions (Rosenberg et al., 1994) and sustainable harvesting (FRCC, 1996) were also consulted.

What follows is the report of the Working Group to the Scientific Council. Documentation taken into consideration during the discussions of the Working Group is annexed to this report.

Request of the NAFO Fisheries Commission to the NAFO Scientific Council

The Scientific Council was requested by the NAFO Fisheries Commission to:

> "... *comment on Article 6 [Application of the Precautionary Approach] and Annex II*

*This report initially appeared as NAFO SCS Doc. 97/12 (Serial No. N2911), *"Report of the Ad hoc Working Group of the NAFO Scientific Council on the Precautionary Approach"*, 61 p. Minor editorial changes have been made to clarify a number of statements in the original report and correct several typographical errors.

[Guidelines for Application of Precautionary Reference Points in Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks] of the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks; and provide the following information for the 1997 Annual Meeting of the Fisheries Commission, a report that includes for all stocks under the responsibility of the Fisheries Commission (i.e. cod in 3M and 3NO, American plaice in 3M and 3LNO, yellowtail flounder in 3LNO, witch flounder in 3NO, redfish in 3M and 3LN, Greenland halibut in SA 2+3, capelin in 3NO, shrimp in 3M and squid in SA 3+4):

a) recommendation[s] for the limit and target precautionary reference points described in Annex II indicating areas of uncertainty;

b) information including medium term consideration and associated risk or probabilities which will assist the Commission to develop the management strategies described in paragraphs 4 and 5 of Annex II in the Agreement;

c) information on the research and monitoring required to evaluate and refine the reference points described in paragraphs 1 and 3 in the Agreement Annex II; these research requirements should be set out in order of priority considered appropriate by the Scientific Council; and,

d) any other aspect of Article 6 and Annex II of the Agreement which the Scientific Council considers useful for the implementation of the Agreement's provisions regarding the precautionary approach to capture fisheries."

The Scientific Council was also requested by the Fisheries Commission to: "*...develop criteria to be evaluated during any consideration of possible fisheries reopenings.*"

Presentations Made to the Council on the Precautionary Approach

Five reports were reviewed and discussed by the Scientific Council relative to the Fisheries Commission's requests (ICES, 1997; Thompson and Mace, 1997; Sinclair, 1997; Mace and Sissenwine, 1989; FRCC 1996). In addition, a demonstration was provided to the Council on "FISHLAB: Software for fisheries evaluation and simulation" as this software might be of potential use in calculating precautionary reference points. FISHLAB, developed by M. Smith and L. Kell of the CEFAS Lowestoft Laboratory (UK) consists of a library of Excel and Visual Basic functions, as well as a wide variety of statistical functions, fisheries assessment functions, fisheries prediction functions, and fisheries simulation and evaluation functions. The software is presently available free of charge from the developers.

Highlights of each of the reports are summarized below:

<u>1.Report of the Study Group on the Precautionary Approach to Fisheries Management (ICES, 1997)</u>

i) "The precautionary approach, sustainable development, rational exploitation and responsible fishing have been given a central place in international conferences and agreements devoted to the environment and fisheries... There can be no disagreement that sustainable, productive fisheries require management approaches which ensure a high probability of stocks being able to replenish themselves. Because of the inherent uncertainty in all aspects of fisheries management (assessment, regulation and enforcement), this can only be achieved by taking a precautionary approach. Such an approach needs to be adopted for all aspects of management, *'from planning through implementation, enforcement and monitoring to re-evaluation'* (FAO, 1995, page 7), not just in the scientific bases for advice."

ii) Article 7.5 of the FAO Code of Conduct for Responsible Fisheries (FAO, 1995b), and Article 6 and Annex II of the UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN, 1995) are of particular relevance in the interpretation of the precautionary approach. These international instruments "call for the following <u>technical developments</u>: (1) the determination of reference points, with a priority for limit reference points that define the constraints on long-term sustainability, both in theory and as applicable to each stock; (2) improvements in the methods for dealing with uncertainties, notably in relation to evaluating the risk of either approaching or exceeding the limit reference points; [and] (3) the evaluation of how well alternative harvest control rules either maintain stocks in, or restore them to, healthy states. These developments come in addition to assessments of the size, productivity and state of the stocks, and to improved understanding of their biology, which constitute essential pre-conditions of progress in these new directions."

iii) The scientific advisory implications of the precautionary approach suggest that fisheries scientists should: "(1) explicitly consider and incorporate uncertainty about the state of stocks into management scenarios; explain clearly and usefully the implications of uncertainty to fishery management agencies; (2) propose thresholds which ensure that limit reference points are not exceeded, taking into account existing knowledge and uncertainties; (3) encourage and assist fishery management agencies in formulating fisheries management and recovery plans. To do this effectively may require ... assist[ing] fishery management agencies in the development of coherent, measurable objectives; (4) quantify and advise on the effects of fisheries on target and non target species, and on biodiversity and habitats; (5) provide advice on fishing fleets and multispecies fisheries systems as well as on single stocks; [and] (6) evaluate fisheries management systems incorporating biological, social and economic factors as appropriate."

iv) Implementation of the precautionary approach has a number of significant implications for fishery management agencies and the fishing industry. Among these are: (1) most of the current fishery management regimes were established before the formulation of the precautionary approach and are not fully in accordance with the precautionary approach. Management agencies will therefore need to implement the precautionary approach to numerous aspects of current practice; (2) the precautionary approach requires that uncertainty be allowed for in both the understanding of the state of the stocks and the effects of future management actions. "This implies that when less is known, fishery management agencies should adopt a more cautious choice. This may require a change in culture towards a management approach less focused on and influenced by short-term considerations, and more concerned with long-term sustainability"; (3) all desirable management objectives cannot usually be met simultaneously and in the precautionary approach fishery management agencies would derive trade-offs between competing objectives in consultation with interested parties, and translate these into measurable factors such as levels of fishing mortality; (4) the way that fishery management agencies attempt to restrict and manage fisheries exploitation (e.g. TACs, effort controls, technical measures, etc) has implications on the way scientific advice is provided and also for the quality of data acquired and the subsequent use of these data in assessments; "it should be obvious that the precision of the advice decreases when the quality of data deteriorates"; and (5) the precautionary approach requires that fishery management agencies find effective means to restrict fishing mortality within safe biological limits. If there are no means to effectively implement precautionary management advice, the advice itself cannot ensure resource sustainability.

v) Based on the distinctions between target and limit reference points given in Annex II of the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks (see Appendix 2), "reference points stated in terms of fishing mortality rates or biomass, or in other units, should be regarded as signposts giving information on the status of the stock in relation to predefined limits that should be avoided or targets that should be aimed at in order to achieve the management objective... The introduction of the concept of limit reference points to be avoided with a high probability may in some cases complicate the utilization of target reference points, especially when the precision of the data is low and the uncertainties are high. In such cases, it may be necessary to aim for a fishing mortality rate lower than the target in order to ensure that the limit is not exceeded."

vi) A provisional list of reference points was developed (see Appendix 5) which contains a number of reference points which could be considered as limit reference points. Limit reference points are to be avoided, thus the probability of exceeding these values must, by definition, be very low. Within ICES, "the precautionary basis for advice given by ACFM will be that, for a given stock, the probability of exceeding the limit reference point will be no greater than 5% in any given year." This implies that ACFM must recommend that fishing mortality stays below a value considerably lower than the fishing mortality limit reference point. This type of upper bound on fishing mortality (which is significantly below the limit reference point) will be known as the precautionary fishing mortality (F_{pa}). When a fishery is managed such that the annual fishing mortality is at or below F_{pa}, there should be only a low probability that the realized fishing mortality is not sustainable. Similar considerations pertain to biomass limit reference points. Thus, a precautionary biomass level B_{pa} will be determined that is sufficiently higher than the limit biomass reference point to assure with high probability that stock biomass is far above the limit biomass level. Target reference points (either in terms of fishing mortality or biomass) should be more conservative than the precautionary reference points.

vii) Limit, precautionary, and target reference points should be stock specific. The distance between the precautionary reference point and the limit reference point will depend on the data available and their precision, as well as the uncertainties of other parameters such as the environment. The greater the uncertainties, the greater the need to be precautionary. Although some guidance on calculating reference points is provided in the Report, it will be the task of the ICES Methods Working Group to provide ICES Assessment Working Groups with complete guidelines for determining these limit and precautionary reference points.

viii) As part of the precautionary approach, control rules should be implemented which relate target and precautionary reference points to stock conditions. These rules may be formulated in terms of fishing mortality, fishing effort, or catch - and should be implemented as changes in catch or fishing mortality contingent upon (or in anticipation of) changes in stock biomass. Such decision rules should be established at the outset so that any needed actions are specified in advance of the actual situation. More stringent conservation measures should be applied as stock status worsens. Recovery plans for rebuilding depleted stocks should have control rules to regulate fishing mortality and catches in a pre-agreed way as stock biomass increases. Rebuilding programs are most effective when large reductions in fishing mortality are implemented immediately, rather than when small reductions are phased in over long periods of time. Rebuilding generally proceeds more rapidly when exploitation patterns are improved at the same time. It may also be desirable to restore a stock to (1) a heterogeneous age structure to rebuild population fecundity and buffer against recruitment failure; and (2) a wide spatial distribution to spread risk at spawning over a broad range of environmental conditions.

2. The Evolution of Precautionary Approaches to Fisheries Management, with Focus on the United States (Thompson and Mace, 1997)

i) The precautionary approach gained prominence as a result of the Rio Declaration and Agenda 21. Principle 15 of the Rio Declaration, formulated at the 1992 United Nations Conference on Environment and Development (UNCED), states that "in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Subsequently, the precautionary approach has been embodied in: (a) the 1995 FAO Code of Conduct for Responsible Fisheries; (b) the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas; and (c) the Agreement for the Implementation of the Provisions of the United Nations Convention of the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. Annex II of the latter requires that target and limit reference points be used and stipulates that "Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low" and target reference should not be exceeded on average. Paragraph 7 prescribes that the fishing mortality rate which generates MSY should be regarded as a minimum standard for limit reference points. This combination of requirements implies that fishing mortality should always be well below F_{MSY}. This is a significant departure from typical fisheries management practice where F_{MSY} is usually treated as a target (and often exceeded), rather than as a limit.

ii) A small number of organizations and nations have already adopted one or more aspects of the precautionary approach and/or have recently conducted studies aimed at interpreting/evaluating the approach as it applies to their fisheries. These include: CCAMLR (Convention for the Conservation of the Antarctic Marine Living Resources); IPHC (International Pacific Halibut Commission); Canada [see FRCC, 1996]; New Zealand, and Australia.

iii) In the United States, recent amendments (September 1996) to the Magnuson Act (the act which governs U.S. marine fishery management activities) have injected many elements of the precautionary approach into the management of marine fishery resources. The amended Act, renamed the Magnuson-Stevens Act, includes new definitions of overfishing, overfished, and optimum yield; requires the establishment of objective and measurable criteria for determining the status of a stock or stock complex; and mandates specific remedial action in the event that overfishing is occurring or if a stock or stock complex is overfished. Sustainability is a key theme in the Magnuson-Stevens Act. Optimum yield [defined as the amount of fish that will provide the greatest benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems] is now prescribed on the basis of MSY (it can never be greater than MSY). In the case of an overfished fishery, the new Act requires rebuilding to the MSY level. As used implicitly in the new Act, "to 'overfish' means to fish at a rate or level that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis. "Overfished" is used in the new Act in two senses: "first, to describe any stock or stock complex that is subjected to overfishing, and second, to describe any stock or stock complex whose size is sufficiently small that a change in management practices is required to achieve an appropriate level and rate of rebuilding. In either sense, "overfished" stocks must be rebuilt.

iv) The Magnuson-Stevens Act further requires that each Fishery Management Plan (FMP) specify objective and measurable status determination criteria for identifying when the stocks or stock complexes covered by the FMP are overfished. A possible interpretation of this requirement is that the stock determination criteria contain two components: a maximum fishing mortality rate and a minimum stock size level. Since the Act mandates that overfished stocks be rebuilt to the MSY level, an MSY control rule will be required to prescribe limits on fishing mortality as a function of stock biomass [so that sustained application of the rules actually results in rebuilding to MSY]. Obviously, any such rule will also define the rate of rebuilding for all other stocks below the MSY level. Choosing an MSY control rule is the key because it establishes the maximum fishing mortality threshold and plays a role in defining the minimum stock size threshold. Given that OY can never be greater than MSY, the MSY control rule would also define an upper bound on any OY control rule that might be specified.

v) Management of the U.S. EEZ portion of the North Pacific (eastern Bering Sea, Aleutian Island Region and the Gulf of Alaska) is a example where the application of the precautionary approach has been very successful. In 1990, an objective and measurable definition of the overfishing level (OFL) was adopted which provided an upper limit on the amount of fish that could be harvested in any given year. Harvest control laws were implemented in 1996 which were organized in six tiers according to the types of data and information available for a given stock. However, irrespective of tier level, catch targets (ABC) are set well below the overfishing level (OFL) thereby maintaining a buffer between the overfishing level and the catch target. When a stock is above the biomass level associated with MSY (i.e. B_{MSY}), neither the ABC nor the OFL harvest rates varies with stock size. However, if the stock size falls below B_{MSY}, both the ABC and OFL harvest rates decrease linearly as a function of stock size, down to a value of zero at a very low stock size level (typically 5% of B_{MSY}). Although the absolute magnitudes of the ABC and OFL rates vary, the ratio between them remains constant. The minimum buffer between the two rates is established by setting the OFL harvest rate at the arithmetic mean (AM) of the probability density function of F_{MSY}, while capping the ABC harvest rate at the harmonic mean (HM). Since the HM is always less than the AM (and the ratio of the HM to the AM decreases as uncertainty increases), greater uncertainty always corresponds to greater caution - a highly desirable feature.

3. Biological Reference Points Relevant to a Precautionary Approach to Fisheries Management: an Example for Southern Gulf Cod (Sinclair, 1997)

i) The precautionary approach guidelines contained in Annex II of the UN Straddling Stocks Agreement calls for the estimation of stock-specific fishing mortality and biomass reference points related to maximum sustainable yield (i.e. F_{MSY} and B_{MSY}). For many stocks, the necessary information to calculate these reference points is not available. Management strategies for these stocks have typically been based on yield-per-recruit (YPR) and spawning stock biomass per recruit (SSB/R) analyses, not stock/recruitment relationships or stock production models.

ii) Using data from the southern Gulf of St. Lawrence cod stock (NAFO 4TVn(N-A)), age-structured production modeling was conducted to estimate F_{MSY} and B_{MSY}, and to evaluate the effects of changes in size at age, partial recruitment at age, and uncertainty in the stock/recruitment relationship on reference points calculated from production models vs those calculated from YPR models.

iii) "Point estimates and median bootstrap estimates of F_{MSY} and B_{MSY} were virtually identical (0.23 and 207,000 t, respectively) indicating that bootstrapping was reliable." Ninety-five percent of the F_{MSY} estimates were between 0.153 and 0.359, while 95% of the B_{MSY} estimates were between 160,000 t and 325,000 t. Cumulative frequency distribution curves were calculated and displayed in the form of risk curves. Using these curves and adopting a risk averse approach to select a limit B_{MSY} with a low probability (20%) of exceeding the true B_{MSY} resulted in a limit B_{MSY} value of about 240,000 t. Similarly using the same 20% rule to select a fishing mortality limit reference point that would have a low probability of exceeding the true value, resulted in a limit F_{MSY} value of about 0.20.

iv) Management actions implied by changes in size at age or by partial recruitment at age would be quite different depending on whether production models or YPR models were being used. Decreases in size at age had little impact on $F_{0.1}$ [which remained relatively stable] but produced significant declines in F_{MSY} values suggesting that target fishing mortality rates should have been reduced based on the stock production modeling results. Similarly, YPR analyses were relatively insensitive to changes in the age of full recruitment, but F_{MSY} markedly declined in the age-structured production analyses as age at full recruitment declined. However, these results need to be tempered by several of the assumptions used in the production analyses (i.e. a rather simple approach was used to estimate equilibrium stock biomass; a constant knife-edge maturity ogive was applied; and fecundity was assumed to be a simple function of weight).

4. Biological Reference Points for New Zealand Fisheries Assessments (Mace and Sissenwine, 1989)

This document was considered to be a possible aid in developing approaches to determining limit and target reference points in both data-rich and data-poor circumstances.

5. A Discussion of Practical Considerations in Developing Re-Opening Criteria (FRCC, 1996)

The experience of the Fisheries Resource Conservation Council (FRCC) in developing criteria for re-opening fisheries was reviewed. In recent years, the FRCC has been pursuing a process of deliberation and consultation on when and how to re-open fisheries which presently are closed. A detailed account of this process is given in the October 1996 FRCC report *Building the Bridge – 1997 Conservation Requirements for Atlantic Groundfish* (FRCC, 1996). As background for the FRCC consultations, a list of stock status indicators was developed to characterize the status, growth potential, and exploitability of a stock (e.g. total biomass; spawning biomass; recruitment; growth; stock age composition; geographical distribution; fish condition factor; physical environment; etc).

There was agreement that any indicators used for decision-making should be (a) simple; (b) reliable; and (c) widely understood. Indicators that relate directly to stock abundance (biomass, recruitment, age structure) were considered to be more closely linked to stock status than indicators such as habitat or condition factor. Indicators that are easy to calculate and understand - and which can also be rapidly evaluated - are highly desirable in order to minimize the time lag between information acquisition and decision-making and to allow decisions to be made soon enough to have the most impact. All fishery participants should be able to understand how indicator values are derived and agree upon the utility and reliability of these values.

Once stock status indicators have been identified which satisfy the requirements of clarity, simplicity, and reliability, the question remains how to use them in considering a decision to re-open a fishery. The FRCC acknowledged that the Precautionary Approach must be used to ensure that fisheries are only re-opened when there is sufficient certainty that "(1) fish stocks are in good enough shape; and (2) the re-opened fishery can operate in a conservationist manner, keeping fishing mortality to a low enough level." The FRCC noted that it was "crucial that BOTH of these conditions be satisfied".

A review of the stock conditions that prompted fishery closures indicated that the following conditions generally prevailed at the time of closure:

(1) Low stock size (e.g. declining trends followed by the lowest survey estimates on record);

(2) Low recruitment;

(3) Low growth (as evidenced by declines in mean weight at age in catch and/or survey samples);

(4) Low fish condition factor (a measure of the physiological state of fish which may affect reproductive capacity);

(5) Loss of spawning components (in some stocks);

(6) Contraction of geographical distribution; and

(7) Changes in migration patterns.

Clearly, re-opening of a fishery should not occur until stock conditions have significantly improved from those that existed at the time of closure. To determine whether such improvements have actually transpired, however, an evaluation of stock status indicators ("the report card") must be performed to decide, guided by the precautionary principle, whether the most crucial indicators have reached acceptable levels (i.e. levels sufficient to support fishing activity). For the FRCC discussions, the "half-way point" (midway between the low level that existed when the fishery was closed and the average level over a recent period), was selected as the benchmark level denotative of sufficient improvement for each indicator.

The "report card" compares past and current values for each stock status indicator and depicts these in relation to the "half-way point". This framework provides a simple approach to defining conditions (criteria) that should be satisfied prior to re-opening fisheries.

While "reference points or conditions at closure" are NOT substitutes for long-term reference points based on stock dynamics, they serve to capture the conditions that prompted the closures. In essence, they constitute valuable guideposts that - in the context of the Precautionary Approach - delimit danger zones to be avoided in the future.

Endorsement of the Precautionary Approach by the Scientific Council

After reviewing the development, evolution and application of the precautionary approach in fisheries management, the Scientific Council endorsed the precautionary approach as described in Article 6 and Annex II of the UN Agreement of the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (i.e. see Appendix 1 and 2). In addition, the Council intends to use the practical guidance given in FAO 1995 (Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions; see Appendix 4 for the precautionary guidelines elaborated for fishery research) on how to exercise such precaution.

The Council recognizes that implementation of the precautionary approach will be a challenging and ongoing process. To address this challenge in a rigorous and objective fashion, the Council has initiated development of a framework and action plan, and arranged for a *Scientific Council Workshop on the Precautionary Ap-*

proach to Fisheries Management[2]. This Workshop, to be chaired by the Chairman of the Scientific Council, will meet for 10 days at NAFO Headquarters during March 1998 to address the following terms of reference.

(1) Describe procedures for determining limit and target reference points under various levels of stock-specific information;

(2) Determine the limit and target precautionary reference points for all stocks under the responsibility of the NAFO Fisheries Commission (i.e. cod in 3M and 3NO, American plaice in 3M and 3LNO, yellowtail flounder in 3LNO, witch flounder in 3NO, redfish in 3M and 3LN, Greenland halibut in SA 2+3, capelin in 3NO, shrimp in 3M and squid in SA 3+4).

(3) Specify decision rules (e.g. courses of action) to achieve target reference points and to avoid exceeding limit reference points;

(4) Develop criteria to be used in consideration of possible fisheries re-openings.

(5) Identify data collection and monitoring activities required to reliably evaluate resource status with respect to reference points;

(6) Define research requirements to improve the quantification and evaluation of uncertainty (i.e., risk analysis) as well as methodological developments required to reduce uncertainty; and

(7) Indicate time frames and funding required to successfully implement the precautionary approach.

General Principle of the Precautionary Framework

The Scientific Council, recognizing the need to apply the precautionary approach in providing scientific advice, proposes the following provisional framework. This framework prescribes the requisite actions to be taken for controlling fishing mortality in relation to various levels of spawning stock biomass and pre-determined, stock-specific reference points.

Paragraph 7 of Annex II of the UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (see Appendix 2) states that:

> "*The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For fish stocks which are not overfished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold. For overfished stocks, the biomass which would produce maximum sustainable yield can serve as a rebuilding target.*"

Given these guidelines, the Scientific Council framework defines three reference points for biomass and three reference points for fishing mortality, *viz:*

Biomass Reference Points

$\mathbf{B_{lim}}$ The level of spawning stock biomass that the stock should not be allowed to fall below.

$\mathbf{B_{buf}}$ A level of spawning stock biomass, above $\mathbf{B_{lim}}$, that acts as a buffer to ensure that there is a high probability that $\mathbf{B_{lim}}$ is not reached. The more uncertain the estimate of $\mathbf{B_{lim}}$ is, the **higher** the value of $\mathbf{B_{buf}}$, and the greater the distance between $\mathbf{B_{lim}}$ and $\mathbf{B_{buf}}$. When $\mathbf{B_{buf}}$ is reached, immediate action is required to ensure stock rebuilding.

$\mathbf{B_{tr}}$ The target recovery level. In accord with Annex II of the UN Agreement of the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, for overfished stocks this could be the total stock biomass level which would produce maximum sustainable yield (MSY).

Fishing Mortality Reference Points

$\mathbf{F_{lim}}$ The rate of fishing mortality that should not be exceeded. In accord with Annex II of the UN Agreement of the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, this level should be no higher than the fishing mortality rate which generates MSY.

$\mathbf{F_{buf}}$ A fishing mortality rate below $\mathbf{F_{lim}}$ that acts as a buffer to ensure that there is a high probability that $\mathbf{F_{lim}}$ is not reached. As such, on average, $\mathbf{F_{buf}}$ should not be exceeded. The more uncertain the estimate of $\mathbf{F_{lim}}$ is, the **lower** the value of $\mathbf{F_{buf}}$, and the greater the distance between $\mathbf{F_{lim}}$ and $\mathbf{F_{buf}}$.

$\mathbf{F_{target}}$ The target fishing mortality depending on management objectives. This is a level below or equal to $\mathbf{F_{buf}}$.

The general, overall objectives of the precautionary approach to management may then be summarized as follows:

[2] The draft report of this Workshop (held 17-27 March 1998) was issued as NAFO SCS Doc. 98/1 (Serial No. N2987), 60 p.

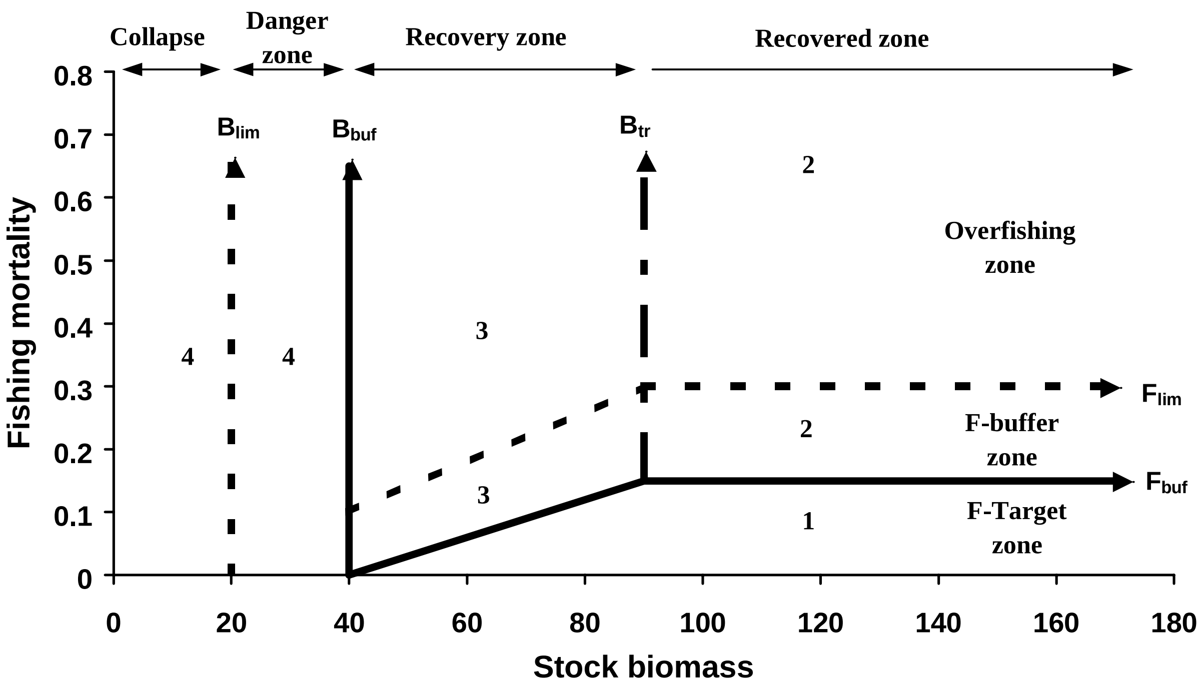

Figure 1. Schematic of the framework for implementation of the precautionary approach.

1. Ensure that spawning stock biomass (**SSB**) is well above the buffer level ($\mathbf{B_{buf}}$) [which by definition is above the biomass limit reference point ($\mathbf{B_{lim}}$)];

2. Maintain fishing mortality such that, on average, it does not exceed $\mathbf{F_{buf}}$, and which will allow the stock to increase towards $\mathbf{B_{tr}}$ and ultimately be maintained at the $\mathbf{B_{tr}}$ level.

These objectives may be defined in shorthand as follows:

1. Ensure $SSB >> B_{buf} > B_{lim}$
2. Maintain $F_{target} <= F_{buf} < F_{lim}$

Schematically, this framework is portrayed in Figure 1 which depicts the courses of action to be taken for given combinations of fishing mortality (F) and spawning stock biomass (B). Spawning stock biomass is represented on the horizontal axis; the three vertical arrows represent the biomass reference points described above. These reference points divide the figure into 4 biomass regions - labeled from left to right as **Collapse**, **Danger Zone**, **Recovery Zone**, and **Recovered Zone**. The level of fishing mortality is shown on the vertical axis; three zones are delimited by the $\mathbf{F_{lim}}$ and $\mathbf{F_{buf}}$ fishing mortality reference points; these are labeled **Overfishing Zone**, **F-buffer Zone** and **F-Target Zone**.

Within each of the joint biomass/fishing mortality zones depicted in Figure 1, a specific course of action is specified by reference to a numerical label from 1 to 4. The courses of action corresponding to these numeric labels are given below:

<u>Course of Action 1</u>

Current Stock Status:	At or above $\mathbf{B_{buf}}$
Current F:	Below $\mathbf{F_{buf}}$
Action:	Continue to fish below $\mathbf{F_{buf}}$.

<u>Course of Action 2</u>

Current Stock Status:	At or above $\mathbf{B_{tr}}$
Current F:	Above $\mathbf{F_{buf}}$
Action:	Reduce F to $\mathbf{F_{buf}}$ or below over a predetermined time horizon.

<u>Course of Action 3</u>

Current Stock Status:	Below $\mathbf{B_{tr}}$; above $\mathbf{B_{buf}}$
Current F:	Above $\mathbf{F_{buf}}$
Action:	Reduce F towards $\mathbf{F_{buf}}$ or below so as to ensure B increases towards $\mathbf{B_{tr}}$ over a predetermined time horizon. Note that $\mathbf{F_{buf}}$ is lower in the recovery zone than in the recovered zone.

Course of Action 4

Current Stock Status:	Below $\mathbf{B_{buf}}$
Current F:	Level not relevant
Action:	Close fishery; initiate precautionary monitoring of stock, with a view to reopening the fishery only when predetermined reopening criteria are satisfied.

Determination of Precautionary Reference Points with Respect to Data Availability and Data Quality

The reference points for biomass and fishing mortality should be selected in accordance with the precautionary approach framework (as described above). The specific reference metric, however (as given in Appendix 5), may vary according to the quantity and quality of the data available for a given stock. As well, the quantification of uncertainty associated with the reference points will vary with data quality and quantity.

Therefore, the association of the three precautionary reference points ($_{lim}$, $_{buf}$, and $_{tr}$) with the appropriate candidate metrics must take account of the available data. The following discussion illustrates the derivation of each precautionary reference point with respect to three levels of data richness - from very rich (e.g. age-structured population model) to very poor (only catch and/or survey data).

The three levels of information considered, each with a varying amount of richness, are given below.

Level 1: Data-Rich Environment. Age-structured population model, incorporating catch at age with auxiliary information, that provides reliable estimates of current F, recruitment, and biomass. The uncertainty of the limit and threshold reference points, and the risk of exceeding thresholds, are determined. Limit reference points may be derived from production models, stock-recruitment analyses, and yield and spawning stock biomass per recruit analyses. The uncertainty associated with estimates of current F and biomass may be derived from the precision of annual population parameter estimates. The reference points, F_{buf} and B_{buf} are defined in relation to F_{lim} and B_{lim}, respectively; the difference between the limit and the buffer reference point is a function of the uncertainty associated with annual estimates of F and biomass.

As examples, the following candidate measures may be used to determine limit reference points:

$F_{lim} = (F_{MSY}, F_{max}, F_{med})$
$F_{buf} = F_{lim}e^{-2s}$

$B_{lim} = (MBAL, B_{loss})$
$B_{buf} = B_{lim}e^{+2s}$
$B_{tr} = B_{MSY}$

Level 2: Data-Moderate Environment. Non-age-structured (production) population model with auxiliary information that provides reliable estimates of current biomass. Information on exploitation pattern, growth and natural mortality is available. Limit reference points may be derived from production models, relative stock-recruitment analyses (based on survey data) and yield and spawning stock biomass per recruit analyses. The uncertainty associated with estimates of current F and biomass may not be available. Biomass trends and recruitment patterns may be derived from research vessel surveys.

As examples, the following candidate measures may be used to determine limit reference points:

$F_{lim} = (F_{MSY}, F_{max}, F_{30\%})$
$F_{buf} = (M, 0.5*F_{MSY})$

$B_{lim} = B_{loss}$
$B_{buf} = 2/3\ B_{MSY}$
$B_{tr} = B_{MSY}$

Level 3: Data-Poor Environment. Information on catch trends is available with some auxiliary information. Information on exploitation pattern and growth may not be available. Limit reference points may be derived from relative stock-recruitment analyses (based on survey data). Estimates of current F and biomass, as well as the uncertainty associated with these estimates, are not likely to be available. Biomass trends and recruitment patterns may be derived from research vessel surveys.

As examples, the following candidate measures may be used to determine limit reference points:

$F_{lim} = F_{30\%}$ SPR
$F_{buf} = M$

$B_{lim} = 0.2 * B_{max}$ (survey index)
$B_{buf} = 0.5 * B_{max}$ (survey index)

The Scientific Council evaluated various reference points applicable to each stock for which advice was requested. Results were collated and are summarized in Table 1. Data for each stock were collected using the data forms depicted in Tables 2 and 3.

Reference points vary among stocks, depending on information richness. For those stocks under moratorium (e.g. 3NO cod and 3LNO plaice), biomass indices were given in terms of survey biomass estimates. A similar approach was used in considering possible pre-

Table 1. Possible candidates for reference points under the Precautionary Framework for stocks under the responsibility of the NAFO Fisheries Commission. P = Provisional Reference Point; L = Limit Reference Point; T = Target Reference Point; Q = Qualitative Consideration.

Source	Reference Point	Cod 3M	Cod 3NO	Plaice 3M	Plaice 3LNO	Yellowtail 3LNO	Witch 3NO	Redfish 3M	Redfish 3LN	G. halibut 2+3LMNO	Capelin 3NO	Squid 3-4	Shrimp 3M
Catches	% LTA						P	P	P		P	P	P
Indices	B_{loss}	L	L	L	L	L	L		L	L			
	% Max (e.g. 20%)	L	L	L	L	L	L		L	L			
	% Max (e.g. 50%)	T	T	T	T	T	T		T	T			
	$B_{at\ closure}$		L	L	L	L	L						
	$R_{at\ closure}$		L	L	L	L	L						
Y/R	$F_{0.1}$	T	T		T	T		T	T	T			
	F_{max}	L	L		L	L		L	L	L			
	Age at F_{max}	L	L		L	L		L	L	L			
SSB/R	$F_{\%SPR\ (e.g. 20\%)}$	L	L		L	L				L			
	$B_{\%Bvirgin\ (e.g.\ 20\%)}$	L	L		L	L				L			
S/R Plot	F_{low}	T	T		T	T							
	F_{med}	L	L		L	L							
	F_{high}	L	L		L	L							
	F_{loss}	L	L		L	L							
	MBAL	L	L		L	L							
S/R Model	$B_{\%R\ (e.g.\ 50\%)}$	?	?		?								
Production	B_{MSY}	T	T		T	T				T			
	F_{MSY}	L	L		L	L				L			
	2/3 F_{MSY}	T	T		T	T				T			
	F_{crash}	L	L		L	L				L			
Other	Geographic range	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Migration pattern	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Spawning season	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Loss of component	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Age/size structure	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Maturity	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Fish condition	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Environment	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	

Footnote: These candidates for precautionary reference points are provided here as examples only of the types of reference points that could be provided; this list is not meant to be all encompassing. For shrimp in 3M, candidates for reference points are to be identified at the fall [1997] assessment meeting.

Table 2. Sample form to summarize available data on various stock status indicators that may be useful in determining reference points.

Indicator		Long-Term Average (19 - 19)	Max/Min Values & Years: Max (19)	Max/Min Values & Years: Min (19)	Status at Closure (19)	Present Status (19)	Comments on Stock Status
Calculated Indicators from last analytical assessment (19)	Total Biomass (mt)						
	Spawning Biomass (mt) (Age +)						
	Recruitment Levels Age ; Millions of Fish						
Data from Scientific Surveys (Mean #/wt Per Tow)	Total Abundance Index (#/tow)						
	Total Biomass Index (wt/tow)						
	Recruitment Index (#/tow) Age ;						
Changes in Spatial/Temporal Distributions of the Stock and/or Fishery							
Changes in Recruitment Levels or Indices							
Changes in Catch Age/Size Composition							
Changes in Fishery Exploitation Pattern							
Changes in Survey Age/Size Composition							
Changes in Natural Mortality Rate							
Changes in Diet and Feeding Patterns							
Changes in Prey and/or Predator Abundance							
Changes in Average Size Length/Weight at Age							
Changes in Average Length/Age at Maturity							
Changes in Spawning Patterns (Time/Duration/Area)							

Table 3. Sample form to list data availability for calculation of reference points.

Commercial fishery data	Data available now	Data available some time ago	Year data/assessment
Landings			
Catch			
Effort			
CPUE			
Catch-at-length			
Catch-at-age			
Weight-at-age			
Maturity-at-age			
Survey data			
Abundance indices			
Biomass indices			
Density index (e.g. mean CPUE)			
Length composition			
Age composition			
Weight-at-age			
Maturity data			
Length-weight conversion factor			

cautionary reference points for stocks where fisheries are open but where data are minimal (e.g. 3M cod, 3M redfish, and 3LN redfish).

Action Plan for the Development of a Framework on the Precautionary Approach[3]

The Scientific Council (SC) proposes the following action plan for implementing the Precautionary Approach to Fisheries Management for stocks in the NAFO Regulatory Area.

June 1997:

At its June meeting, the Scientific Council: (a) reviewed the evolution and application of the precautionary approach in fisheries management throughout the world; (b) developed a draft framework for consideration by the NAFO Fisheries Commission; and (c) identified possible candidates for limit and target reference points.

Summer 1997:

ICES Comprehensive Fisheries Evaluation (COMFIE) Working Group Meeting. Members of the Scientific Council will work by correspondence to review the results of the ICES COMFIE WG meeting and evaluate the applicability of various precautionary reference points for stocks in the NAFO Regulatory Area.

September 1997:

At the September 1997 meeting of the Fisheries Commission, the Chairman of the Scientific Council will propose that the Fisheries Commission: (a) adopt the draft framework for implementation of the Precautionary Approach; (b) endorse the Action Plan developed during the June meeting of the SC meeting; and (c) endorse the convening of the *Scientific Council Workshop on the Precautionary Approach to Fisheries Management* in March 1998.

September 1997 (and November 1997):

Scientific Council to discuss the draft framework for implementing the Precautionary Approach with respect to shrimp stocks in the NAFO area.

September 1997:

ICES Annual Science Conference (Baltimore USA). The 1997 ICES Annual Science Conference will include a Theme Session (Session V) on the "Application of the Precautionary Approach in Fisheries and Environmental Management". Members of the SC will take note of the information discussed at this Session, and review

[3] Activities in the Action Plan that occurred between June 1997 and March 1998 were reviewed at the March 1998 Scientific Council Workshop on the Precautionary Approach to Fisheries Management. See Sections I and II in the "Report of the Scientific Council Workshop on the Precautionary Approach to Fisheries Management", NAFO SCS Doc. 98/1, 64 p.

these findings at the March 1998 *Scientific Council Workshop on the Precautionary Approach to Fisheries Management*.

March 1998:

Scientific Council Workshop on the Precautionary Approach to Fisheries Management.

June 1998:

Meeting of the Scientific Council. The Council will implement the Precautionary Approach in formulating advice for 1999 for stocks in the NAFO Regulatory Area and specify precautionary reference points wherever possible.

September 1998:

Meeting of the Fisheries Commission. The Chairman of the Scientific Council will table a report at the September 1998 meeting of the Fisheries Commission entitled "Framework for Implementing the Precautionary Approach to Fisheries Management within NAFO".

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APPENDIX 1

UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks

Article 6. Application of the Precautionary Approach

1. States shall apply the precautionary approach widely to conservation management and exploitation of straddling fish stocks and highly migratory fish stocks in order to protect the living marine resources and preserve the marine environment.

2. States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures.

3. In implementing the precautionary approach, States shall:

(a) improve decision-making for fishery resource conservation and management by obtaining and sharing the best scientific information available and implementing improved techniques for dealing with risk and uncertainty;

(b) apply the guidelines set out in Annex II and determine, on the basis of the best scientific information available, stock-specific reference points and the action to be taken if they are exceeded;

(c) take into account, inter alia, uncertainties relating to the size and productivity of the stocks, reference points, stock condition in relation to such reference points, levels and distribution of fishing mortality and the impact of fishing activities on non-target and associated or dependent species, as well as existing and predicted oceanic, environmental and socio-economic conditions; and

(d) develop data collection and research programmes to assess the impact of fishing on non-target and associated or dependent species and their environment, and adopt plans which are necessary to ensure the conservation of such species and to protect habitats of special concern.

4. States shall take measures to ensure that, when reference points are approached, they will not be exceeded. In the event that they are exceeded, States shall, without delay, take the action determined under paragraph 3 (b) to restore the stocks.

5. Where the status of target stocks or non-target or associated or dependent species is of concern, States shall subject such stocks and species to enhanced monitoring in order to review their status and the efficacy of conservation and management measures. They shall revise those measures regularly in the light of new information.

6. For new or exploratory fisheries, States should adopt as soon as possible cautious conservation and management measures, including inter alia, catch limits and effort limits. Such measures should remain in force until there are sufficient data to allow assessment of the impact of the fisheries on the long-term sustainability of the stocks, whereupon conservation and management measures based on that assessment shall be implemented. The latter shall, if appropriate, allow for the gradual development of the fisheries.

7. If a natural phenomenon has a significant adverse impact of the status of straddling fish stocks or highly migratory fish stocks, States shall adopt conservation and management measures on an emergency basis to ensure that fishing activity does not exacerbate such adverse impact. States shall also adopt such measures on an emergency basis where fishing activity presents a serious threat to the sustainability of such stocks. Measures taken on an emergency basis shall be temporary and shall be based on the best scientific evidence available.

APPENDIX 2

ANNEX II. UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks

Guidelines for the Application of Precautionary Reference Points in Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks

1. A precautionary reference point is an estimated value derived through an agreed scientific procedure, which corresponds to the state of the resource and of the fishery, and which can be used as a guide for fisheries management.

2. Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points. Limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points are intended to meet management objectives.

3. Precautionary reference points should be stock-specific to account, inter alia, for the reproductive capacity, the resilience of each stock and the characteristics of fisheries exploiting the stock, as well as other sources of mortality and major sources of uncertainty.

4. Management strategies shall seek to maintain or restore populations of harvested stocks, and where necessary associated or dependent species, at levels consistent with previously agreed precautionary reference points. Such reference points shall be used to trigger pre-agreed conservation and management action. Management strategies shall include measures which can be implemented when precautionary reference points are approached.

5. Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low. If a stock falls below a limit reference point or is at risk of falling below such a reference point, conservation and management action should be initiated to facilitate stock recovery. Fishery management strategies shall ensure that target reference points are not exceeded on average.

6. When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set. Provisional reference points may be established by analogy to similar and better-known stocks. In such situations, the fishery shall be subject to enhanced monitoring so as to enable revision of provisional reference points as improved information becomes available.

7. The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For stocks which are not overfished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold. For overfished stocks, the biomass which would produce maximum sustainable yield can serve as a rebuilding target.

APPENDIX 3

FAO CODE OF CONDUCT FOR RESPONSIBLE FISHERIES

Article 7.5 Precautionary Approach

Paragraph 7.5.1: States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures.

Paragraph 7.5.2: In implementing the precautionary approach, States should take into account, inter alia, uncertainties relating to the size and productivity of the stocks, reference points, stock condition in relation to such reference points, levels and distribution of fishing mortality and the impact of fishing activities, including discards, on non-target and associated and dependent species as well as environmental and socio-economic conditions.

Paragraph 7.5.3: States and subregional or regional fisheries management organizations and arrangements should, on the basis of the best scientific evidence available, inter alia, determine:

a) stock specific target reference points, and, at the same time, the action to be taken if they are exceeded; and

b) stock specific limit reference points and, at the same time, the action to be taken if they are exceeded; when a limit reference point is approached, measures should be taken to ensure that it will not be exceeded.

Paragraph 7.5.4: In the case of new or exploratory fisheries, States should adopt as soon as possible cautious conservation and management measures, including, inter alia, catch limits and effort limits. Such measures should remain in force until there are sufficient data to allow assessment of the impact of the fisheries on the long-term sustainability of the stocks, whereupon conservation and management measures based on that assessment should be implemented. The latter should, if appropriate, allow for the gradual development of the fisheries.

Paragraph 7.5.5: If a natural phenomenon has a significant adverse impact of the status of living aquatic resources, States should adopt conservation and management measures on an emergency basis to ensure that fishing activity does not exacerbate such adverse impact. States should also adopt such measures on an emergency basis where fishing activity presents a serious threat to the sustainability of such resources. Measures taken on an emergency basis should be temporary and should be based on the best scientific evidence available.

Article 12 Fisheries Research

Paragraph 12.13: States should promote the use of research results as a basis for the setting of management objectives, reference points and performance criteria, as well as for ensuring adequate linkage between applied research and fisheries management.

APPENDIX 4

PRECAUTIONARY APPROACH TO FISHERIES

Part 1: Guidelines on the precautionary approach to capture fisheries and species introductions
(FAO Fisheries Technical Paper No. 350, Part 1. Rome, FAO. 1995 52 p.)

Section 4. Precautionary Approach to Fishery Research

51. Application of the precautionary approach to fishery management depends on the amount, type and reliability of information about the fishery and how this information is used to achieve management objectives. The precautionary approach to fishery management is applicable even with very limited information. Research to increase information about a fishery usually increases potential benefits while reducing the risk to the resource. The scientific and research input that is required for the precautionary approach to fisheries is considered under the following headings; management objectives, observations and information base, stock assessment and analysis and decision processes.

Section 4.1 The Role of Research in Establishing Management Objectives

52. There is a valid scientific role in helping managers develop objectives, so that scientific input to the overall management process is as effective as possible in achieving management intent. The precautionary approach requires continuing and anticipatory evaluation of the consequences of management actions with respect to management objectives. Scientific evaluation of consequences with respect to management objectives requires explicit definition of quantifiable criteria for judgement. An important scientific contribution is in the development of operational targets, constraints and criteria that are both scientifically usable and have management relevance.

53. Research is required to help formulate biological objectives, targets and constraints regarding the protection of habitat, the avoidance of fishing that significantly reduces population reproductive capacity, and reduces the effects of fishing on other (e.g., non-target) species. Combined with biological research, research on socio-economics and the structure of fishing communities is needed to formulate management objectives.

54. Until stock specific research leads to the establishment of alternative operational target based on research and practical experiences, a precautionary approach would seek to: (a) maintain the spawning biomass at a prudent level (i.e., above 50% of its unexploited level), (b) keep the fishing mortality rate relatively low (i.e., below the natural mortality rate), (c) avoid intensive fishing on immature fish, (d) protect the habitat.

Section 4.2 Observation Processes and Information Base

55. A precautionary approach to fisheries requires explicit specification of the information needed to achieve the management objectives, taking account of the management structure, as well as of the processes required to ensure that these needs are met. Periodic evaluation and revision of the data collection system is necessary.

56. A precautionary approach would include mechanisms that ensure that, at a minimum, discarded catch, retained catch and fishing effort are accurate and complete. These mechanisms could include use of observers and identification of incentives for industry co-operation.

57. Recognizing that resource users have substantial knowledge of fisheries, a precautionary approach makes use of their experience in developing an understanding of the fishery and its impacts.

58. The precautionary approach is made more effective by development of an understanding of the sources of uncertainty in the data sampling processes, and collection of sufficient information to quantify this uncertainty. If such information is available it can be explicitly used in the management procedure to estimate the uncertainty affecting decisions and the resulting risk. If such information is not available, a precautionary approach to fishery management would implicitly account for the unknown uncertainty by being more conservative.

59. Precautionary fishery monitoring is part of the precautionary approach. It includes collection of information to address issues and questions that are not only of immediate concern but which may reasonably be expected to be important for future generations in case objectives are changed. Information should be collected on target species, bycatch, harvesting capacity, behaviour of the fishery sector, social and economic aspects of the fishery, and ecosystem structure and function. Measures of resource status independent of fishery data are also highly desirable.

60. The precautionary approach relies on the use of a history of experience with the effects of fishing, in the fishery under consideration and/or similar fisheries, from which possible consequences of fishing can be identified and used to guide future precautionary management. This requires that both data and data collection methods are well documented and available.

61. There are many management processes and decision structures used throughout the world, such as regional management bodies, co-management, community-based management, and traditional management practices. Research is need to determine the extent to which different management processes and decision structures promote precaution.

Section 4.3 Assessment Methods and Analysis

62. Biological reference points for overfishing should be included as part of the precautionary approach.

63. A precautionary approach specifically requires a more comprehensive treatment of uncertainty than is the current norm in fishery assessment. This requires recognition of gaps in knowledge, and the explicit identification of the range of interpretations that is reasonable given the present information.

64. The use of complementary sources of fishery information should be facilitated by active compilation and scientific analysis of the relevant traditional information. This should be accompanied by the development of methods by which this information can be used to develop management advice.

65. Specifically the assessment process should include:

a. scientific standards of evidence (objective, verifiable and potentially replicable), should be applied in the evaluation of information used in analysis;

b. a process for assessment and analysis that is transparent, and

c. periodic, independent, objective and in-depth peer review as a quality assurance.

66. A precautionary approach to assessment and analysis requires a realistic appraisal of the range of outcomes possible under fishing and the probabilities of these outcomes under different management actions. The precautionary approach to assessment would follow a process of identifying alternative possible hypotheses or states of nature, based on the information available, and examining the consequences of proposed management actions under each of these alternative hypotheses. This process would be the same in data-rich and data-poor analyses. A precautionary assessment would, at the very least, aim to consider: (a) uncertainties in data; (b) specific alternative hypotheses about underlying biological, economic and social processes, and (c) calculation of the theoretical response of the system to the range of alternative management actions. A checklist for consideration under these headings is found in the following paragraphs.

67. Sources of uncertainty in data include: (a) estimates of abundance; (b) model structure; (c) parameter values used in models; (d) future environmental conditions; (e) effectiveness of implementation of management measures; (f) future economic and social conditions; (g) future management objectives, and (h) fleet capacity and behaviour.

68. Specific alternative hypotheses about underlying biological, economic and social processes to be considered include: (a) depensatory recruitment or other dynamics giving rapid collapse; (b) changes in behaviour of the fishing industry under regulation, including changes in coastal community structure; (c) medium-term changes in environmental conditions; (d) systematic underreporting of catch data; (e) fishery-dependent estimates of abundance not being proportional to abundance; (f) changes in price or cost to the fishing industry; and (g) changes in ecosystems caused by fishing.

69. In calculating (simulating) the response of the system to a range of alternative management actions, the following should be taken into account:

a. short-term (1-2y) projections alone are not sufficient for precautionary assessment; time frames and discount rates appropriate to inter-generational issues should be used, and

b. scientific evaluation of management options requires specification of operational targets, constraints and decision rules. If these are not adequately specified by managers, then precautionary analysis requires that assumptions be made about these specifications, and that the additional uncertainty resulting from these assumptions be calculated. Managers should be advised that additional specification of targets, constraints and decision rules are needed to reduce this uncertainty.

70. Methods of analysis and presentation will differ with circumstances, but effective treatment of uncertainty and communication of the results are necessary in a precautionary assessment. Some approaches that could prove useful are:

a. when there are no sufficient observations to assign probabilities to different states of nature that have occurred, decision tables could be used to represent different degrees of management caution through Maximin and Minimax criteria;

b. where the number of different states of nature and the number of potential management actions considered are small, but probabilities can be assigned, decision tables can be used to show the consequences and probabilities of all combinations of these, and

c. where the range of states of nature is large, the evaluation of management procedures is more complex, requiring integration across the various sources of uncertainty.

71. A precautionary approach to analysis would examine the ability of the data collection system to detect undesirable trends. Where the ability to detect trends is low, management should be cautious.

72. Since concern regarding the reversibility of the adverse impacts of fishing is a major reason for the precautionary approach, research on reversibility in ecosystems should be an important part of developing precautionary approaches.

APPENDIX 5

SOME COMMONLY USED REFERENCE POINTS

(From: Updated Draft Report of the ICES Study Group on the Precautionary Approach to Fisheries Management, ICES CM 1997/Assess:7)

RP	Definition	Data Needs	Possible PA-Use
$F_{0.1}$	F at which the slope of the Y/R curve is 10% of its value near the origin	Weight at age, natural mortality, exploitation pattern	
F_{max}	F giving the maximum yield on a Y/R curve	Weight at age, natural mortality, exploitation pattern	LIMIT[1]
F_{low}	F corresponding to a SSB/R equal to the inverse of the 10% percentile of the observed R/SSB	Data series of spawning stock size and recruitment, weight and maturity at age, natural mortality, exploitation pattern.	
F_{med}	F corresponding to a SSB/R equal to the inverse of the 50% percentile of the observed R/SSB	Data series of spawning stock size and recruitment, weight and maturity at age, natural mortality, exploitation pattern.	LIMIT[1]
F_{high}	F corresponding to a SSB/R equal to the inverse of the 90% percentile of the observed R/SSB	Data series of spawning stock size and recruitment, weight and maturity at age, natural mortality, exploitation pattern.	
F_{MSY}	F corresponding to Maximum Sustainable Yield from a production model or from an age-based analysis using a stock recruitment model	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship or general production models	LIMIT[1]
2/3 F_{MSY}	2/3 of F_{MSY}	as above	
$F_{20\% SPR}$	F corresponding to a level of SSB/R which is 20% of the SSB/R obtained when F=0	Weight and maturity at age, natural mortality, exploitation pattern.	LIMIT[1]
F_{crash}	F corresponding to the higher intersection of the equilibrium yield with the F axis as estimated by a production model; could also be expressed as the tangent through the origin of a Stock-Recruitment relationship.	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship	LIMIT[1]
F_{loss}	F corresponding to a SSB/R equal to the inverse of R/SSB at the Lowest Observed Spawning Stock - LOSS	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship	LIMIT[1]
F_{comfie}	F corresponding to the minimum of $_{Fmed}$, F_{MSY} and F_{crash}		LIMIT[1]
F >= M	Empirical (for top predators)	M and sustainable F's for similar resources	
F < M	As above (for small pelagic species)	M and sustainable F's for similar resources	
Z_{mbp}	Level of total mortality at which the maximum biological production is obtained from the stock	Annual data series of standard catch rate and total mortality	
B_{MSY}	Biomass corresponding to Maximum Sustainable Yield from a production model or from an age-based analysis using a stock recruitment model	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship or general production models	LIMIT[1]
MBAL	A value of SSB below which the probability of reduced recruitment increases	Data series of spawning stock size and recruitment (not necessarily from an VPA)	LIMIT[1]
$B_{50\% R}$	The level of spawning stock at which average recruitment is one half of the maximum of the underlying stock-recruitment relationship.	Stock recruitment relationship (not necessarily from an VPA)	LIMIT[1]
$B_{90\% R, 90\% Surv}$	Level of spawning stock corresponding to the intersection of the 90th percentile of observed survival rate (R/S) and the 90th percentile of the recruitment observations	Data series of spawning stock size and recruitment	LIMIT[1]
$B_{20\% B\text{-}virg}$	Level of spawning stock corresponding to a fraction (here 20%) of the unexploited biomass. Virgin biomass is estimated as the point where the replacement line for F=0 intersects the stock- recruitment relationship or as the biomass from a spawning stock per recruit curve when F=0 and average recruitment is assumed	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship	LIMIT[1]
B_{loss}	Lowest observed stock size	Data series of spawning stock size	LIMIT[1]

[1] Not all limit reference points are intrinsically equal, and their interpretation depends on the specifics of each particular case they are applied to. For example, F_{max} can in some cases be considered as a target, when it is well defined and corresponds to a sustainable fishing mortality, while it would be a limit when it is ill defined and/or corresponds to unsustainable fishing mortality. Similarly F_{MSY}, that is suggested as a minimal international standard for a limit reference point in the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, could in some particular cases be considered a target. F_{crash} on the other hand is an extremely dangerous level of fishing mortality at which the probability of stock collapse is high. The probability of exceeding F_{crash} should therefore be very low.